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RESEARCH MEMORANDUM

PRELIMINARY FLIGHT MEASUREMENTS OF THE STATIC
LONGITUDINAL STABILITY AND STALLING
CHARACTERISTICS OF THE DOUGLAS D-558-II
RESEARCH AIRPLANE (BUAERO. NO. 37974)

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NATIONAL ADVISORY COMMITTEE
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SUMMARY

Brief flight measurements were made of the longitudinal stability and stalling characteristics of the Douglas D-558-II (BuAero. No. 37974) research airplane. Longitudinal-stability measurements were made with stabilizer settings of 1.3° and 3.4° leading edge up. A stable variation of elevator position for trim with Mach number was obtained throughout the Mach number range tested with either stabilizer setting. No abrupt longitudinal trim changes occurred up to the highest Mach numbers reached: 0.76 with the 1.3° stabilizer setting and 0.87 with the 3.4° stabilizer setting. In the clean condition, the airplane tended to nose up near the stall; this nosing up indicated longitudinal instability. The nosing-up tendency could be controlled with the elevator. In the landing condition the airplane was longitudinally stable up to the stall. At the stall the data indicate that the airplane became longitudinally unstable. This instability was not noticed by the pilot probably because of the yawing and rolling motions which also occurred at the stall.

INTRODUCTION

The NACA is engaged in a flight-research program utilizing the Douglas D-558-II (BuAero. No. 37974) research airplane. The D-558-II airplanes were designed for flight research in the transonic speed range and were procured for the NACA by the Bureau of Aeronautics of the Navy Department. This paper presents some results obtained on the static longitudinal stability and stalling characteristics of the airplane during the first two NACA flights. Some measurements of the

dynamic lateral stability characteristics of the airplane, also obtained during the first two NACA flights, are reported in reference 1.

AIRPLANE

The Douglas D-558-II airplanes have sweptback wing and tail surfaces and were designed for combination turbojet and rocket power. The airplane being used in the present investigation (BuAero. No. 37974) does not yet have the rocket engine installed. This airplane is powered solely by a J-34-WE-40 turbojet engine which exhausts out of the bottom of the fuselage between the wing and the tail. Two jets are used to provide additional thrust for take-off. Both slats and stall-control vanes are incorporated on the wing of the airplane. The wing slats can be locked in the closed position or they can be unlocked. When the slats are unlocked, the slat position is a function of the angle of attack of the airplane. The airplane is equipped with an adjustable stabilizer. Dive brakes are located on the rear portion of the fuselage. No aerodynamic-balance or control-force booster system is used on any of the control surfaces. Hydraulic dampers are installed on all control surfaces to aid in preventing any control-surface flutter. Photographs of the airplane are shown in figures 1 and 2 and a three-view drawing is shown in figure 3. Pertinent airplane dimensions and characteristics are listed in table I.

INSTRUMENTATION

Standard NACA recording instruments were installed in the airplane to measure the following quantities:

- Airspeed
- Altitude
- Elevator and aileron wheel force
- Normal, longitudinal, transverse accelerations
- Rolling, pitching, yawing velocities
- Rudder-pedal force
- Sideslip angle
- Stabilizer, elevator, rudder, right-aileron position

Strain gages were installed in the airplane to measure wing and tail aerodynamic loads and twist and bending deflections of the right wing panel.

Since high Mach numbers were not expected in the early flights, a low-speed-type free-swiveling airspeed head was used to measure both

static and impact pressures. This airspeed head was mounted on a boom approximately 8 feet forward of the nose of the airplane. A vane which was used to measure sideslip angle was mounted below the same boom approximately 6 feet forward of the nose of the airplane. (See fig. 1.)

TESTS, RESULTS, AND DISCUSSION

This paper presents some results obtained on the static longitudinal stability and stalling characteristics of the airplane during the first two NACA flights. The airspeeds, altitudes, and Mach numbers presented in this paper have not been corrected for the position error of the airspeed head or any error inherent in the airspeed head itself.

Figure 4 shows the variation of elevator angle, elevator force, and pressure altitude with Mach number during two dives which were made with different stabilizer settings. The stabilizer settings given in figure 4 are measured with respect to the fuselage reference line. For the dive with a stabilizer setting of 3.4° , leading edge up, the wing slats were unlocked. Therefore, the slat position probably varied during the dive, with the slat being open a greater amount at low Mach numbers than at high Mach numbers. For the dive with a stabilizer setting of 1.3° , leading edge up, the slats were locked in the closed position. When the stabilizer setting was 3.4° , leading edge up, increasing pull forces on the elevator control were required for trim as the Mach number was increased. However, the increase in pull force required for trim does not indicate stick-free instability as the elevator wheel force was not trimmed to zero at any point in the Mach number range covered. With a stabilizer setting of 1.3° , leading edge up, a highly stable variation of elevator force with speed was obtained. The variation of elevator position with Mach number was highly stable throughout the Mach number range tested with either stabilizer setting. The differences in the slopes of the curves of elevator position against Mach number for the different stabilizer settings are probably due to the differences in slat position and to the differences in distortion of the horizontal stabilizer and elevator. No abrupt longitudinal trim changes occurred with either stabilizer setting up to the highest Mach numbers reached: 0.76 with a 1.3° stabilizer setting and 0.87 with the 3.4° stabilizer setting. Much of the scatter in the elevator force data is due to the friction in the elevator control system. The normal acceleration during the dives varied between 0.85g and 1.25g.

Figure 5 shows a time history of an approach to a stall in the clean condition. As shown on the normal-acceleration curve, a light buffeting first occurred at an indicated airspeed of approximately 165 miles per hour. The buffeting increased in intensity as the airspeed decreased.

The pilot noted a tendency for the airplane to nose up near the stall. This nosing-up tendency, indicating longitudinal instability, is also shown in figure 5 between times 17 and 19 seconds where the elevator angle is decreasing but the pitching velocity is positive and the acceleration is increasing. The maximum lift of the airplane was probably not reached during the run because when the airplane tended to nose up the pilot reduced the angle of attack.

The maximum value of lift coefficient reached was 1.07 at time 19 seconds. The pilot was required to use the ailerons almost continuously during the run because of a tendency for the airplane to oscillate in yaw and roll. The lateral oscillatory characteristics of the airplane are discussed in reference 1.

A time history of a stall in the landing condition is shown in figure 6. Light buffeting started at about 135 miles per hour and increased in intensity somewhat as the stall was approached. The longitudinal stability of the airplane in the landing condition was positive up to the stall. At the stall the data indicate that the airplane became longitudinally unstable, as shown in figure 6, between 34 and 38 seconds. In this time interval the pilot moved the elevator from 20° up to 10° down, but the normal acceleration remained practically constant and the pitching-velocity curve showed a slight nose up. The instability was not noticed by the pilot probably because of the yawing and rolling motions which also occurred at the stall. The maximum value of lift coefficient reached was 1.43 at time 35 seconds.

SUMMARY OF RESULTS

Brief flight measurements were made of the longitudinal stability and stalling characteristics of the D-558-II (BuAero. No. 37974) research airplane. A stable variation of elevator position for trim with Mach number was obtained throughout the Mach number range tested with stabilizer settings of either 1.3° leading edge up or 3.4° leading edge up. No abrupt longitudinal trim changes occurred up to the highest Mach numbers reached: 0.76 with the 1.3° stabilizer setting and 0.87 with the 3.4° stabilizer setting. In the clean condition, the airplane tended to nose up near the stall; this nosing up indicated longitudinal instability. The nosing-up tendency could be controlled with the elevator. In the landing condition the airplane was longitudinally stable up to the stall. At the stall the data indicate that

the airplane became longitudinally unstable. This instability was not noticed by the pilot probably because of the yawing and rolling motions which also occurred at the stall.

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REFERENCE

1. Sjoberg, Sigurd A.: Preliminary Measurements of the Dynamic Lateral Stability Characteristics of the Douglas D-558-II (BuAero. No. 37974) Airplane. NACA RM L9G18, 1949.

TABLE I
 DIMENSIONS AND CHARACTERISTICS OF THE
 DOUGLAS D-558-II AIRPLANE

Wing:

Root airfoil section (normal to 0.30 chord)	NACA 63-010
Tip airfoil section (normal to 0.30 chord)	NACA 63-012
Total area, sq ft	175.0
Span, ft	25.0
Mean aerodynamic chord, in.	87.301
Root chord (parallel to plane of symmetry), in.	108.508
Tip chord (parallel to plane of symmetry), in.	61.180
Taper ratio	0.565
Aspect ratio	3.570
Sweep at 0.30 chord, deg	35.0
Incidence at fuselage center line, deg	3.0
Dihedral, deg	-3.0
Geometric twist, deg	0
Total aileron area (aft of hinge), sq ft	9.8
Total flap area, sq ft	12.58

Horizontal tail:

Root airfoil section (normal to 0.30 chord)	NACA 63-010
Tip airfoil section (normal to 0.30 chord)	NACA 63-010
Area (including fuselage), sq ft	39.9
Span, in.	71.8
Mean aerodynamic chord, in.	41.75
Root chord (parallel to plane of symmetry)	53.6
Tip chord (parallel to plane of symmetry)	26.8
Taper ratio	0.50
Aspect ratio	3.59
Sweep at 0.30 chord line, deg	40.0
Dihedral, deg	0
Elevator area, sq ft	3.78

Vertical tail:

Airfoil section (parallel to fuselage center line)	NACA 63-010
Area, sq ft	36.6
Height from fuselage center line, in.	98.0
Root chord (parallel to fuselage center line), in.	146.0
Tip chord (parallel to fuselage center line), in.	44.0
Sweep angle at 0.30 chord, deg	49.0
Rudder area (aft of hinge line), sq ft	6.15



TABLE I - Concluded

DIMENSIONS AND CHARACTERISTICS OF THE

DOUGLAS D-558-II AIRPLANE - Concluded

Fuselage:

Length, ft	42.0
Maximum diameter, in.	60.0
Fineness ratio	8.40
Speed-retarder area, sq ft	5.25

Power plant J-34-WE-40
 2 jets for take-off

Airplane weight (full fuel), lb	10,554
Airplane weight (no fuel), lb	8,994
Airplane weight (full fuel and 2 jets), lb	10,969

Center-of-gravity locations:

Full fuel (gear down), percent mean aerodynamic chord	23.4
Full fuel (gear up), percent mean aerodynamic chord	23.9
No fuel (gear down), percent mean aerodynamic chord	24.6
No fuel (gear up), percent mean aerodynamic chord	25.2
Full fuel and 2 jets (gear down), percent mean aerodynamic chord	26.9



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Figure 1.— Front view of Douglas D-558-II (BuAero. No. 37974) research airplane.

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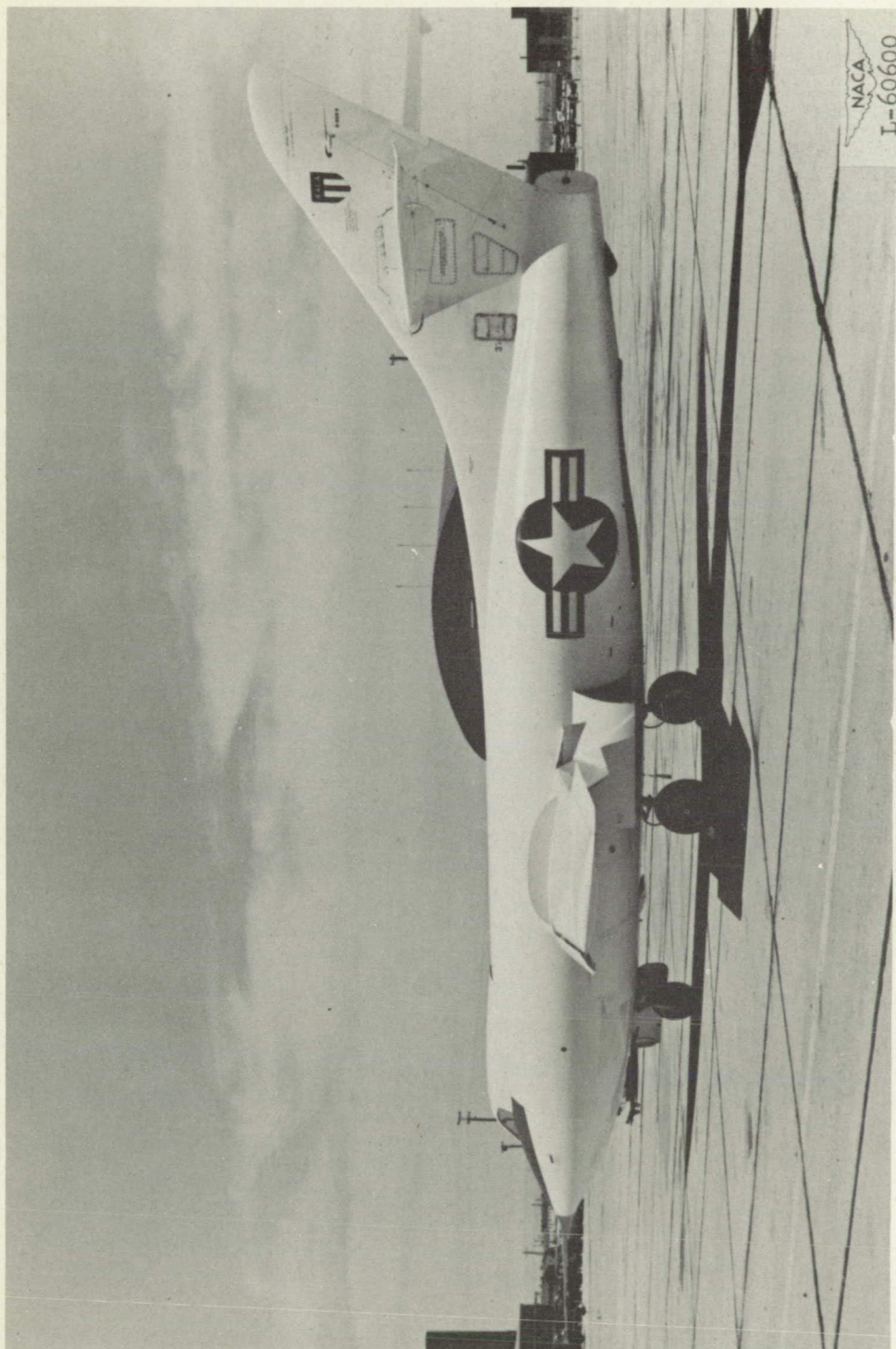


Figure 2.- Three-quarter rear view of Douglas D-558-II (BuAero. No. 37974) research airplane.

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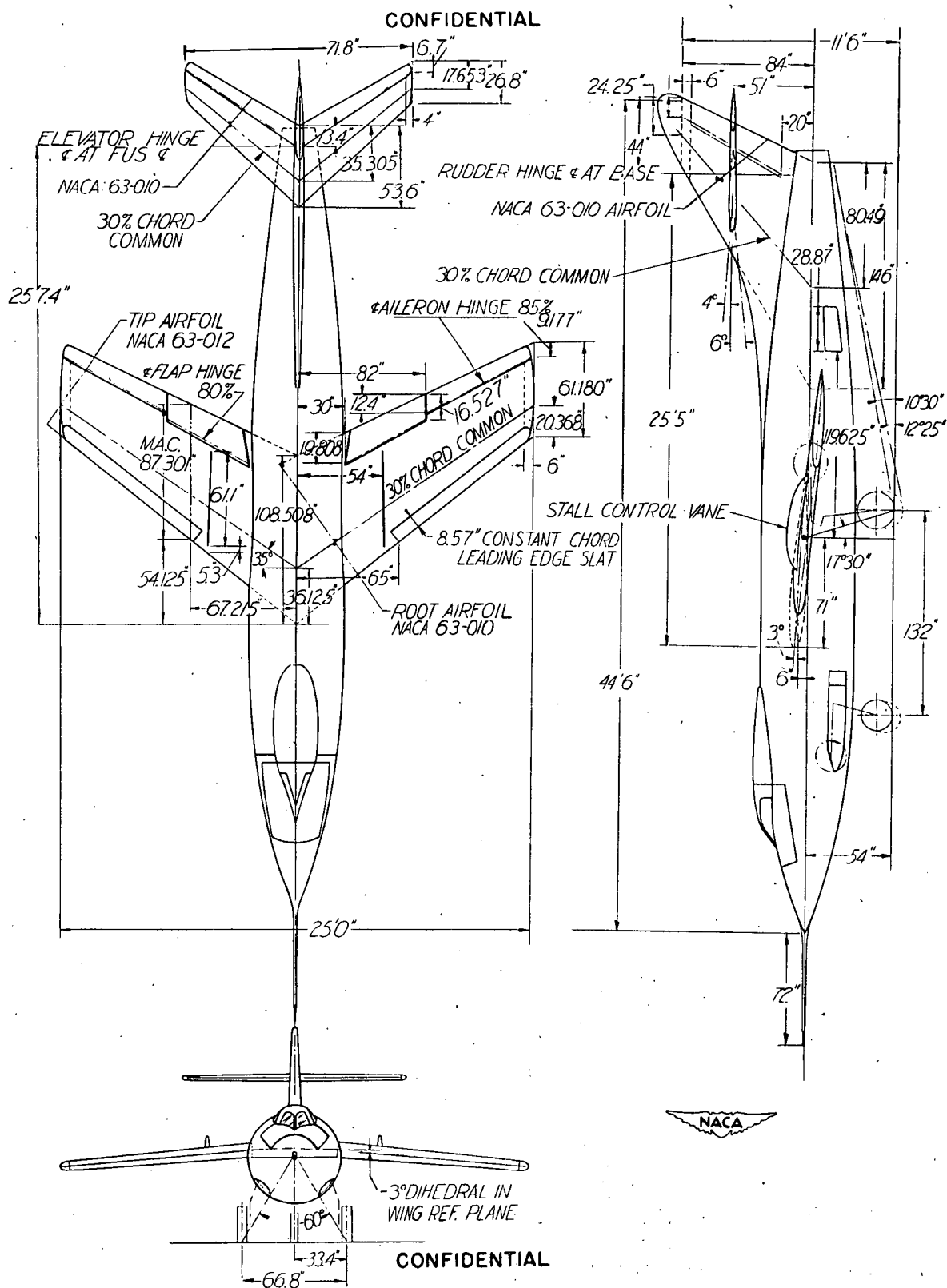


Figure 3.— Three-view drawing of Douglas D-558-II (BuAero. No. 37974) research airplane.

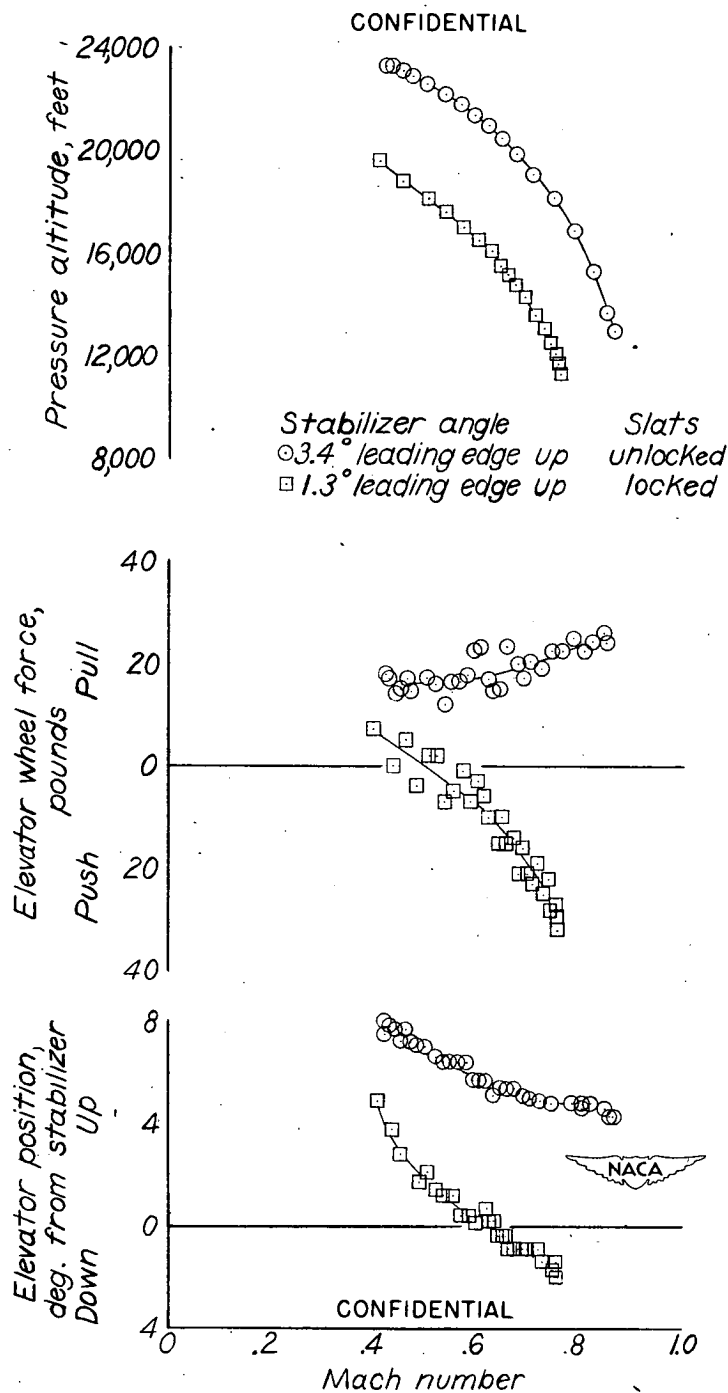


Figure 4.— Static longitudinal stability characteristics of the Douglas D-558-II (BuAero. No. 37974) research airplane with two different stabilizer settings. Flaps up; gear up; military power, engine of 12,500 rpm; center of gravity at 24.9 percent mean aerodynamic chord.

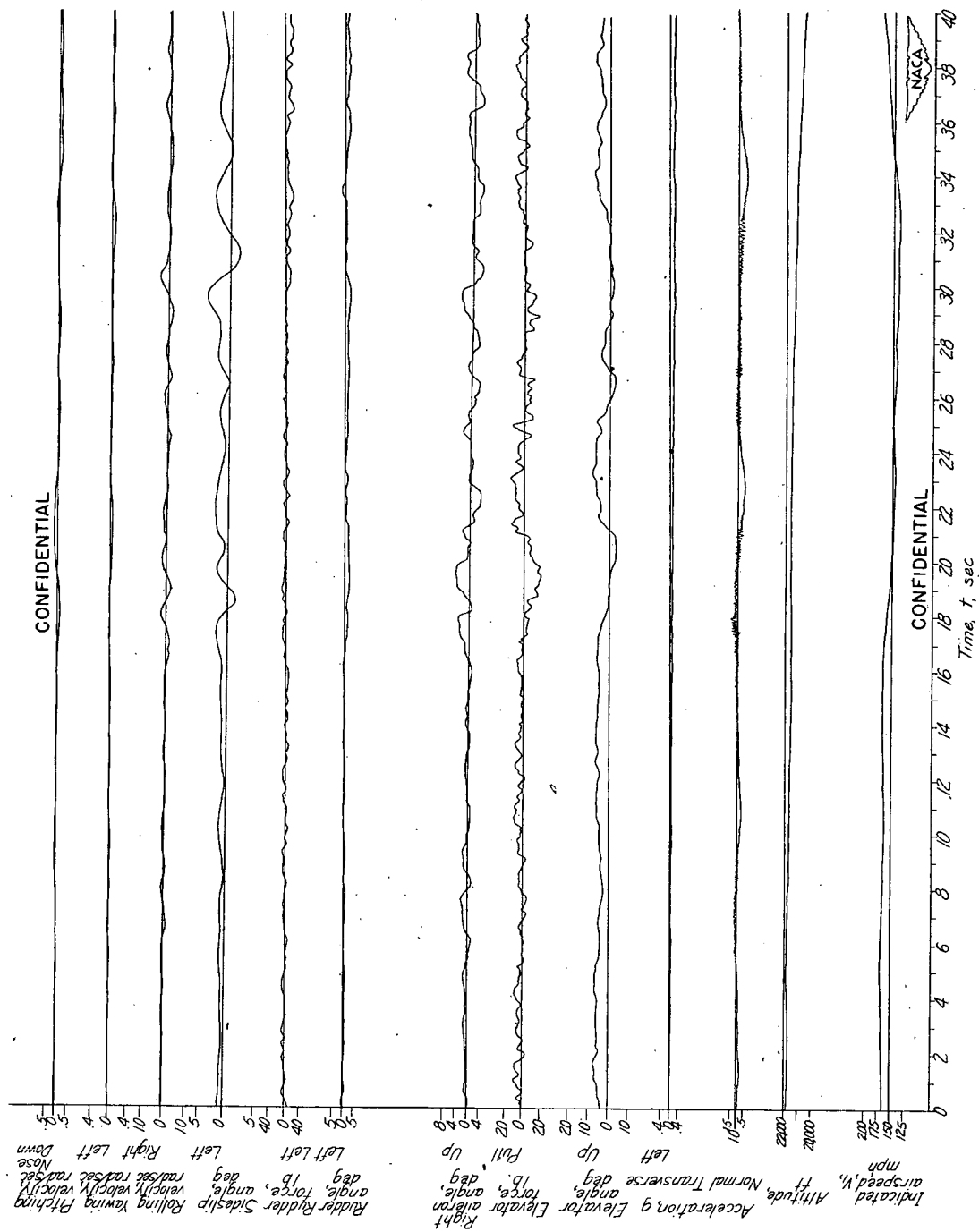


Figure 5.— Time history of an approach to a stall with Douglas D-558-II (BuAero. No. 37974) research airplane. Flaps up; gear up; slats locked; engine, 10,400 rpm; center of gravity at 24.8 percent mean aerodynamic chord; stabilizer setting, 1.3° leading edge up.

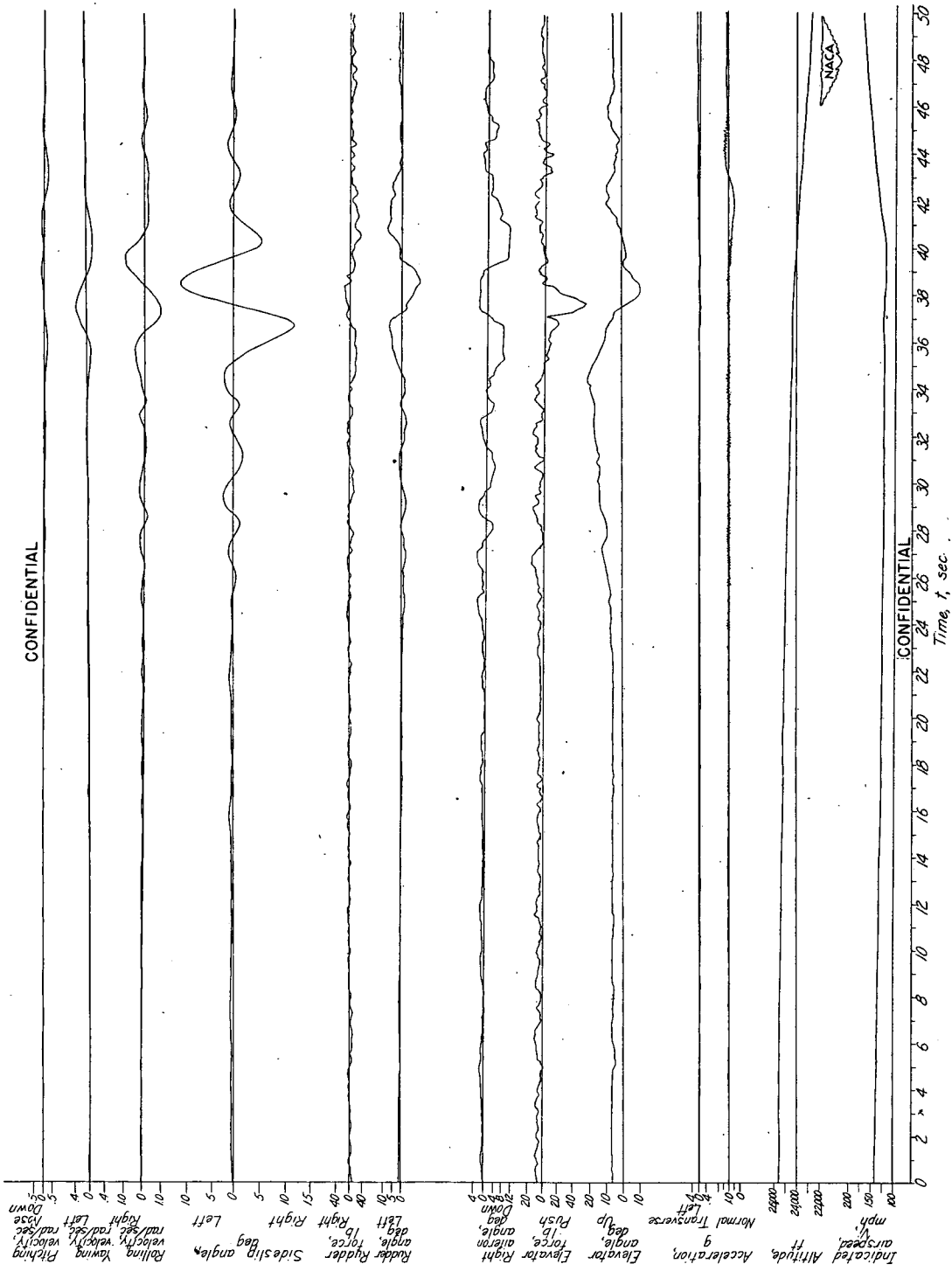


Figure 6.— Time history of stall with Douglas D-558-II (BuAero. No. 37974) research airplane. Flaps down; gear down; slats unlocked; engine, 11,400 rpm; center of gravity at 24.4 percent mean aerodynamic chord; stabilizer setting, 1.3° leading edge up.